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EFFECT OF TIME AND METHOD OF STORAGE ON THE PROPERTIES OF WOOD PELLETS WITH ADDITION OF LIGNIN

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ABSTRACT

Wood pellets are very perspective fuel at this time. This renewable fuel is produced from a solid biomass with consistent quality – low moisture content, high energy content, high density and homogeneous size and shape. However, the problem of pellets is disintegration due to air humidity. This leads to deterioration of the pellets properties due to lose contained energy. Because of this it is necessary to store pellets in a dry environment. One of the options to increase the durability of pellets is adding of additives. In this work were tested two types of wood pellets, reference sample without additive and sample with addition of lignin. Each sample was stored on four different places under different condition. During specific periods of time abrasion resistance,total heating value, moisture content and water tests were determined on these samples.

KEYWORDS: Wood pellets, additive, lignin, abrasion resistance, pellet mill.

INTRODUCTION

With declining reserves of fossil fuels and increasing energy consumption, it is necessary to seek new sources of energy. Biomass plays an increasingly important role in reducing fossil fuel consumption. Pellets are a solid fuel produced from biomass, at present mainly from wood residues. This high-quality biofuel meets in addition to energy, environmental criteria and the criterion of easy to use and safe combustion. Although the consumption of wood pellets in Slovakia can be estimated only for a few thousand tonnes per year but with the gradual erosion of fossil fuels can be estimated that the use of wood pellets will expand. But with the gradual erosion of fossil fuels and their growth rates it can be estimated that the use of wood pellets will expand (Nosek et al. 2010).

Pellets are a form of wood fuel. The shape of pellet is cylindrical with a diameter of 6-10 mm and a length of 10-50 mm manufactured from raw wood (chips, sawdust) made by compression, called pelletizing, usually with no chemical additives. It is a modern form of compaction of biomass, which offers interesting possibilities for the development of renewable energy worldwide. In the use of compacting biomass is dominated by wood residues, which are otherwise not processed and still contain large amounts of energy. Trees are not only intentionally harvested for their manufacture (Židek 2006).

Water has a crucial role in the pelletizing process (Samuelsson et al. 2012). It is found to be the most important factor influencing the pellet quality and it can act as both a binding agent that affect mechanical durability and fines, and as a lubricant that lower the friction in the die resulting in low bulk density and energy consumption (Kaliyan and Morey 2009).

Most pellets are hygroscopic, which means that they absorb water when exposed to it. When fully saturated with water, compressed pellets expand about 3.5 times. This expansion precludes water as a fire-extinguishing media. Further, expansion forces may crack the containment or create an extremely hard and compact plug that requires a jack hammer to remove. (Mani et al. 2007) It is not only water from extinguishment that might cause swelling and degradation of the pellets into "moist sawdust", but also condensation of humid gases formed during oxidation or by a smouldering fire inside the pellets. The condensation might occur both on the pellet surface and the wall and roof of a silo, which then affects the pellets along the wall (Obernberger and Thek 2010, Samuelsson et al. 2012).

Most pellets are also sensitive to humidity in the air and will absorb or expel moisture to a certain level until the equilibrium moisture concentration for pellets is reached. The equilibrium moisture concentration varies for different qualities of pellets and is a function of relative humidity and ambient temperature. The fairly slow rate of sorption is due to the quality and the specific density of the pellets. However, it has been observed that pellets might also swell and "glue" together, for example in a silo, if humid air from the outside is leaking into the pellet storage (Payne 2004, Obernberger and Thek 2010).

In previous studies (Jandačka et al. 2011b, Holubčík et al. 2012) it was observed, that addition of some additives to wood sawdust before pelleting can improve some properties of wood pellets. Similar results were observed in work Berghel et al. 2014, where 1- 4 % of kraft lignin was added to the pellets and it increased pellets mechanical durability and their lengths. In work of Samuelsson et al. (2009) was observed that different biomaterial properties influence the final pellet quality.

The aim of this work was to determine impact of time, storage method and lignin addition in wood pellets to their lifetime in different conditions.

MATERIAL AND METHODS

Used additive

At present, by Austrian and German quality standards, is permitted the content of additives in wood pellets up to 2 percent. In this work lignin was used as an additive to the amount of 2 percent.

As an additive it is considered a substance (ingredient) added to some material (product) in order to improve some of its properties. Usually it happens in practice that with the improving of some characteristics new deficiencies are beginning to be discovered. Because of this it is necessary for each used ingredient to analyse its effects to properties of pellets.

Lignin is a functional organic part of wood. The amount of this substance in the tissues increases by age. Lignin increases their mechanical strength of wood (compression, bending and toughness) and reduced permeability to water, nutrient solutions and metabolites. It also has protective function - mechanically prevents penetration of microorganisms into the wood and some chemically inhibits their activity. Lignin is a complex carbohydrate and is found in the cell walls of all plant materials.

Procedure for experimental production of wood pellets

Pellet production is a complex process and it is necessary that starting material – wood sawdust must certain some conditions. It cannot contain undesirable objects. The largest size of sawdust fraction must be smaller than diameter of holes in the matrix of pellet mill. The humidity of input material should be around 15 %. Manufactured pellets must be cooled and stored properly (Chen et al. 1989).

In the laboratory of University of Zilina has been designed and partially implemented an experimental device for pelletizing according to the scheme in Fig. 1 in accordance with works Wolf et al. 2005, Jandačka et al. 2011a and Holubčík et al. 2012. It consists of input material tank (in which is delivered biomass for production of pellets), crusher (which crush material to fractions of size max. 6 mm in accordance with works Dzurenda and Slovák 2001, Dzurenda 2005 and Dobrowolska et al. 2010), crushed material tank (where the crushed material is temporarily stored), dryer (where is possibly wet material dried for optimal humidity), mixing machine with capacity of 50 dm^3 (where the dried material mixed with water and additive), pellet mill with capacity of 70 – 100 $kg.h^{-1}$ (where the prepared biomass material is pressed into pellets), cooler with fan (final product - pellets are cooled to room temperature) in accordance with work Winowiski 1985 and produced pellets tank (where pellets are temporarily stored before packing).

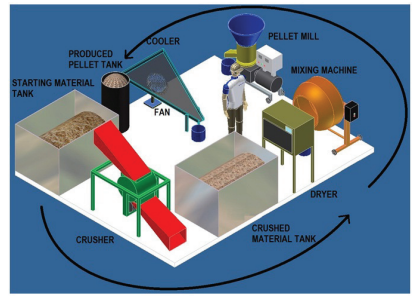

Fig. 1: Experimental device for pelletizing.

This experimental device for pelletizing was used for production of experimental samples of wood pellets. For producing of experimental samples, dendromass - spruce sawdust was used. Spruce sawdust was delivered by external company and their moisture content was about 8-9 %. It was necessary to moisten it to the ideal moisture content about 15 to 20 % due to making the process of pelletization uniform. Increasing moisture was carried out in mixing machine, which was also used for mixing the input material with additional additives. About 15 kg of sawdust was milled and compressed into pellets for each experiment.

One reference sample (A1, B1, C1, D1) without additive was produced and second sample (A2, B2, C2, D2) with added 2 % of lignin.

Storage of wood pellets samples

Produced experimental samples were stored in 4 different conditions:

A. Hermetically closed in a heated room at average temperature of 22.17°C and average relative humidity of 28.7 %.
B. Bulk in a heated room at average temperature of 22.17°C and average relative humidity of 28.7 %.
C. Bulk in unheated room at average temperature of 6.83°C and average relative humidity of 43.7 %.
D. Bulk in external space at average temperature of 3.87°C and average relative humidity of 82.3 %.

Individual samples are marked by letter (A, B, C, D) depending on type of storage and by number depending on used additive (1, 2). So, for example, A2 is sample of wood pellets with addition of lignin hermetically closed in a heated room at average temperature of 22.17°C and average relative humidity of 28.7 %.

Samples were tested immediately after production, 7 days after production, 30 days after production and 60 days after production.

There were 4 properties measured on the produced samples:

- *Moisture content* was measured according to STN EN 14774 (2010) while it was used drying analytical scale RADWAG 50 SX. A sample of pellets (10-30 grams) was placed on a metal plate in the analytical scale. The weight of the wet pellets was recorded. The sample was dried at about 120°C and after that the weight of the dry pellets was recorded. Based on the weight difference the moisture content of samples was calculated. Two measurements for each sample were made and the resulting values were their average (Dzurenda and Jandačka 2010).
- *Total heating* value was determined according to STN EN 14918 (2010) by using of calorimeter LECO AC 500. A sample of wood pellet with weight about 1.0 g was burned in a combustion vessel filled with oxygen to a pressure 31.0 bar. The combustion vessel was immersed in 2.0 dm^3 of distilled water. During burning of sample its temperature increase of water, was measured.
- *Abrasion resistance* was determined as quality parameter according to STN EN 15210 (2010) by using of special device – LignoTester. Some samples were placed in an air stream for 30 or 60 sec. by used program with air pressure 30 mbar, respectively 70 mbar. (Holubčík et al. 2012)
- *Water test* second quality parameter. This method of determining the quality of pellets is only approximate and serves only to compare different samples of wood pellets. From each sample of the produced pellets two large pellets of the same size were selected. Each sample was placed in a glass container filled with water of about 0.2 dm^3. Consequently, time was measured until the pellets disintegrate completely. The longer the disintegration time of pellets meant higher quality of pellets. (Jandačka et al. 2011b).

RESULTS AND DISCUSSION

Moisture content, total heating value, abrasion resistance and water test were determined immediately after production of wood pellets samples. The results of measurements are presented in the Tab. 1.

Tab. 1: Properties of wood pellets samples immediately after production.

Sample	Moisture content (%)	Total heating v value ($MJ.kg^{-1}$)	Abrasion resistance (%)		Water test (sec.)
			30 sec.	60 sec.	
A1, B1, C1, D1	8.52	18.89	98.9	88.3	92
A2, B2, C2, D2	8.15	18.72	99.6	91.9	190.5

Samples of wood pellets were tested 7 days after production. The results of measurements are shown in the Tab. 2.

Tab. 2: Properties of wood pellets samples 7 days after production.

Sample	Moisture content (%)	Total heating value ($MJ.kg^{-1}$)	Abrasion resistance (%)		Water test (sec.)
			30 sec.	60 sec.	
A1	8.02	18.67	98.9	86.4	91
A2	7.63	18.69	99.3	90.5	142
B1	6.63	18.99	98.0	79.0	80
B2	6.74	18.92	99.2	90.8	120
C1	8.32	18.71	98.1	86.7	89
C2	7.99	18.69	99.1	91.8	117.5
D1	1.34	18.52	93.8	77.8	79
D2	9.21	18,48	96.5	83.7	126

Samples of wood pellets were tested 30 days after production. The results of measurements are presented in the Tab. 3.

Tab. 3: Properties of wood pellets samples 30 days after production.

Sample	Moisture content (%)	Total heating value ($MJ.kg^{-1}$)	Abrasion resistance (%)		Water test (sec.)
			30 sec.	60 sec.	
A1	7.2	18.83	95.8	72.9	88
A2	7.27	18.84	98.9	88.1	131
B1	6.42	18.92	98.0	79.8	75
B2	6.34	18.95	98.3	86.1	105
C1	8.87	18.49	98.3	84.6	81.5
C2	8.36	18.64	98.9	90.1	116
D1	12.64	17.51	87.4	63.7	625
D2	12.05	17.73	93.2	68.9	85.5

Samples of wood pellets were tested 60 days after production. The results of measurements are presented in the Tab. 4.

From obtained values were prepared time courses. On the Fig. 2 are time courses of moisture content of reference samples and samples with addition of lignin in unheated room and in exterior. Visible increase of moisture content was shown on samples in exterior figure. Moisture contents of samples in unheated room were relatively steady.

Tab. 4: Properties of wood pellets samples 60 days after production.

Sample	Moisture content (%)	Total heating value (MJ.kg^{-1})	Abrasion resistance (%)		Water test (sec.)
			30 sec.	60 sec.	
A1	7.82	18.68	94.8	67.9	85
A2	7.35	18.76	97.9	83.1	125
B1	5.89	18.73	97.3	77.4	72.5
B2	5.82	18.89	97.8	83.6	100.5
C1	8.83	18.23	97.6	81.0	75
C2	8.26	18.48	98.0	85.1	108
D1	1.93	16.80	84.9	53.9	55
D2	1.94	17.21	90.7	61.4	79.5

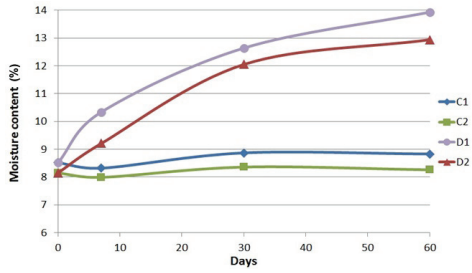

Fig. 2: Time course of moisture content of wood pellets samples storage in unheated room and in exterior.

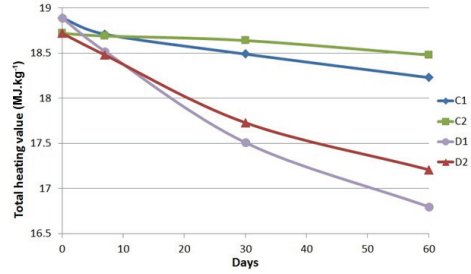

Fig. 3: Time course of total heating value of wood pellets samples storage in unheated room and in exterior.

The Fig. 3 shows that with increasing of moisture content the total heating value of samples stored in exterior decrease rapidly. Reduction of total heating value of samples with addition of lignin was smaller than reference samples.

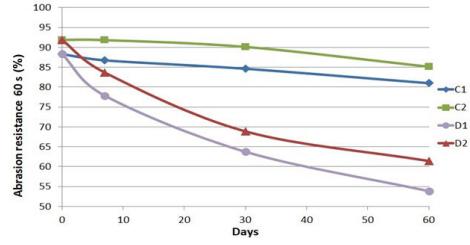

Fig. 4: Time course of abrasion resistance (60 sec.) of wood pellets samples storage in unheated room and in exterior.

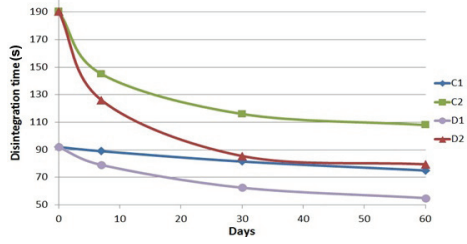

Fig. 5: Time course of disintegration time of wood pellets samples storage in unheated room and in exterior.

Addition of lignin had also impact on mechanical properties. On the Fig. 4 are presented time courses of abrasion resistance (60 sec.) in unheated room and in exterior. There is visible rapid decreasing of abrasion resistance of samples storage in exterior. Samples with addition of lignin have higher strength and stability.

On the Fig. 5 are time courses of disintegration time in water test. Values of disintegration time correspond to abrasion resistance values (Fig. 4) while the addition of lignin increases disintegration time in water test is visible.

Improper storage of wood pellets samples in exterior is also visible on pellet surface. There are more scratches, cracks and imperfections visible on the surface after 60 days in exterior. Fig. 6 shows 10 times zoomed photography of surface of reference sample before and after 60 days storage in exterior.

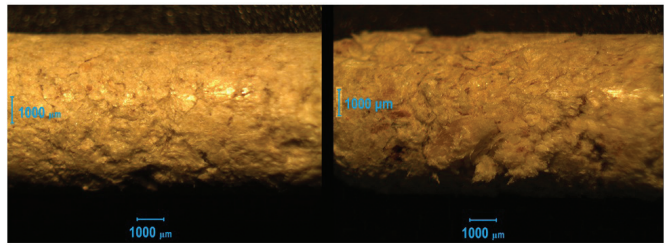

Fig. 6: Picture of 10 times zoomed surface of reference samples before and after 60 days storage in exterior.

Fig. 7 shows 10 times zoomed photography of sample surface with addition of lignin before and after 60 days storage in exterior. Both surfaces (before and after storage) of samples with addition of lignin have fewer cracks and scratches and are smoother in comparison with reference sample surface (Fig. 6). These figures correspond with results in work Stelte et al. 2011, where were tested various temperatures of pellets process.

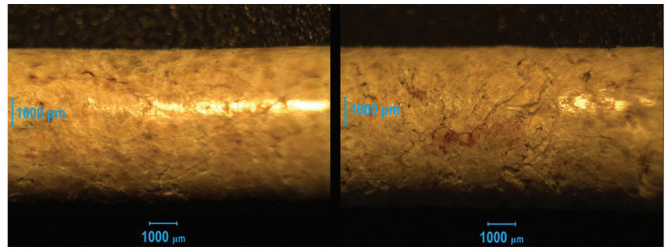

Fig. 7: Picture of 10 times zoomed surface of samples with addition of lignin before and after 60 days storage in exterior.

Samples with addition of lignin has course of moisture content in lower values. It is partially caused by lower value of moisture content of wood pellet samples with addition of lignin before storage in comparison with reference sample. However, this is not only one reason of lower increase of moisture of wood pellet samples with addition of lignin. It can be assumed that due to the addition of lignin into pellets the resistance to moisture is increased. Moisture content also increased with storage time in work Chico-Santamarta et al. (2012), where the moisture content increased from 10.39 to 12.13 % after 48 weeks.

It is interesting to note the differences between samples of wood pellets in total heating value (THV). The Fig. 3 shows that addition of lignin has positive effect on THV. The heat value of samples with lignin was lower in comparison to reference samples. These tests were done immediately after production of samples. But it sufficed only approximately 10 days of storage in exterior and THV of both samples were roughly the same. The similar behaviour

was recorded in storage in unheated room where THV of samples with lignin levelled value of THV approximately after 8 days. Smaller decrease THV of samples with addition of lignin was observed during the whole storage period. Specifically, during 60 days storage in exterior sample with addition of lignin achieved 8.07 % decrement of THV in comparison with 11.06 % decrement with reference samples. These results are similar to work Payne (2004), where also was confirmed that THV is related to moisture content.

Positive effect to abrasion resistance (AR) was observed in samples with addition of lignin. Higher AR of samples with addition of lignin was measured immediately after production and during the whole storage period in comparison with reference samples. It can be said that the addition of 2 % lignin can increase AR about 4 % immediately after production of wood pellets. The results show that addition of lignin can increase AR about 14 % during storage in exterior and about 5 % during storage in unheated room. Results of positive effect of lignin are similar to results from Berghel et al. (2012), where mechanical durability increased from 97.3 % (pellets without lignin) to 99.2 % (pellets with 4.2 % lignin addition) and the pellets lengths increased from 6.6 ± 2.4 mm to 14.5 ± 6.8 mm. Similar results was also observed in work Samuelsson et al. (2009), but there were physical properties after 140 days storage in ideal conditions better.

Water test was realized as the second quality parameter of made wood pellets. Curves of disintegration time (DT) are similar to abrasion resistance courses. Samples with addition of lignin provided the best results in this parameter. DT of samples with addition of lignin was approximately 2 times higher immediately after production and about 45-60 % higher during storage period in exterior in comparison with reference sample. In case of unheated room the DT of sample with lignin was about 32-44 % higher during storage period in comparison with reference sample.

CONCLUSIONS

Addition of lignin during production of wood pellets has relatively high impact on properties and durability of pellets during storage. From the experimental work it was proved that using 2 % of lignin during production of wood pellets markedly increases quality of pellets. This was reflected especially during storage of pellets in external space. Addition of lignin can be recommended for industrial producers of wood pellets, this additive as a substance naturally contained in the wood, has positive impact on wood pellets properties.

The problematic of using additives during production of pellets from biomass is enormous and requires a lot of experience and work.

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